

CLAIM LISTING:

1. (Amended) A method for forming a contact plug of a semiconductor device comprising:

forming an insulating layer on a silicon substrate;
opening a contact hole in the insulating layer, wherein a portion of the silicon substrate is exposed at a bottom of the contact hole; and
selectively growing a silicon epitaxial layer in the contact hole, wherein the selective epitaxial layer comprises a single crystal silicon portion, and a polycrystalline or amorphous silicon portion,
wherein the single crystal silicon portion comprises a substantially conical structure, a base of which substantially covers the exposed portion of the silicon ~~substrate; substrate, and~~
~~further~~ wherein the polycrystalline or amorphous silicon portion fills the remainder of the contact hole; and
wherein the step of opening a contact hole in the insulating layer further comprises:
applying a dry cleaning process to the exposed portion of the silicon substrate;
applying a wet cleaning process to the exposed portion of the silicon substrate;
and
baking the exposed portion of the silicon substrate in H₂;
these steps being completed before the step of selectively growing a silicon epitaxial layer in the contact hole.

2. (Original) The method for forming a contact plug of a semiconductor device according to claim 1:

wherein the step of selectively growing a silicon epitaxial layer in the contact hole further comprises an LPCVD process wherein a reaction gas is a gas mixture comprising MS (SiH₄) and H₂ or a gas mixture comprising DCS (SiCl₂H₂) and H₂ and a dopant gas is PH₃.

3. (Original) The method for forming a contact plug of a semiconductor device according to claim 2:

wherein a flow of MS gas or DCS gas is controlled to be approximately 100 to 500sccm and
a flow of H₂ gas is controlled to be approximately 2,000 to 20,000sccm.

4. (Original) The method for forming a contact plug of a semiconductor device according to claim 2:

wherein a flow of PH₃ gas is controlled to obtain a phosphorus doping concentration in the silicon epitaxial layer between approximately 1×10^{19} to 10^{21} atoms/cc.

5. (Original) The method for forming a contact plug of a semiconductor device according to claim 1:

wherein the step of selectively growing the silicon epitaxial layer is conducted within a pressure range of approximately 1 to 200 Torr.

6. (Cancelled)

7. (Original) The method for forming a contact plug of a semiconductor device according to claim 1 [claim 6]:

wherein the step of applying a dry cleaning process further comprises treating the exposed portion of the silicon substrate using a NF₃/O₂ plasma for approximately 20 to 30 seconds.

8. (Original) The method for forming a contact plug of a semiconductor device according to claim 1 [claim 6]:

wherein the step of applying a wet cleaning process further comprises treating the exposed portion of the silicon substrate using a mixed solution of BOE and H₂SO₄ for approximately 20 to 30 seconds.

9. (Original) The method for forming a contact plug of a semiconductor device according to claim 1 [claim 6]:

wherein the step of baking further comprises treating the exposed portion of the silicon substrate using H₂ at a temperature between approximately 700 and 1,000C for approximately 60 to 300 seconds.

10. (Original) The method for forming a contact plug of a semiconductor device according to claim 1:

wherein the step of selectively growing a silicon epitaxial layer further comprises

growing the single crystal silicon portion using a LPCVD process at a temperature of approximately 600 to 700°C; and then

growing the polycrystalline or amorphous silicon portion at a temperature of approximately 550 to 650°C.

11. (Original) The method for forming a contact plug of a semiconductor device according to claim 10:

wherein the step of selectively growing the silicon epitaxial layer further comprises a LPCVD process using a reaction gas comprising a gas mixture of MS (SiH_4) and H_2 or a gas mixture of DSC (SiCl_2H_2) and H_2 and a dopant gas comprising PH_3 .

12. (Original) The method for forming a contact plug of a semiconductor device according to claim 11:

wherein a flow of MS gas or DCS gas is controlled to be approximately 100 to 500sccm and

a flow of H_2 gas is controlled to be approximately 2,000 to 20,000sccm.

13. (Original) The method for forming a contact plug of a semiconductor device according to claim 12:

wherein a flow of PH_3 gas is controlled to obtain a phosphorus doping concentration in the silicon epitaxial layer between approximately 1×10^{19} to 10^{21} atoms/cc.

14. (Original) The method for forming a contact plug of a semiconductor device according to claim 10:

wherein the step of selectively growing the silicon epitaxial layer is conducted within a pressure range of approximately 1 to 200 Torr.

15. (Original) The method for forming a contact plug of a semiconductor device according to claim 10:

wherein the single crystal silicon portion has a height of approximately 500Å.

16. (Original) The method for forming a contact plug of a semiconductor device according to claim 10:

wherein the step of growing the single crystal silicon portion is completed in approximately 30 to 60 seconds.

17. (Original) The method for forming a contact plug of a semiconductor device according to claim 10:

wherein the step of growing the polycrystalline or amorphous silicon is performed at a temperature of approximately 550 to 610°C.

18. (Original) A method for forming a contact plug of semiconductor device comprising, in sequence, the steps of:

preparing a silicon substrate;

forming an insulating layer on the silicon substrate;

forming a contact hole in the insulating layer to expose a portion of the silicon substrate;

dry cleaning the exposed portion of the silicon substrate;

wet cleaning the exposed portion of the silicon substrate;

inserting the silicon substrate into a LPCVD apparatus;

H₂ baking the exposed portion of the silicon substrate region;

selectively growing an epitaxial single crystal silicon portion on the exposed portion of the silicon substrate at a temperature of approximately 550 to 700°C;

selectively growing a second epitaxial silicon portion on the epitaxial single crystal silicon portion, the second epitaxial silicon portion comprising polycrystalline silicon, amorphous silicon, or a combination thereof, at a temperature of approximately 550 to 700°C, the thickness of the second epitaxial silicon portion being sufficient to render the contact hole at least substantially filled; and

removing the silicon substrate from the LPCVD apparatus.

19. (Original) The method for forming a contact plug of a semiconductor device according to claim 18:

wherein the step of dry cleaning the exposed portion of the silicon substrate further comprises treating the silicon substrate a NF₃/O₂ plasma for approximately 20 to 30 seconds.

20. (Original) The method for forming a contact plug of a semiconductor device according to claim 18:

wherein the step of wet cleaning the exposed portion of the silicon substrate further comprises applying a mixed solution of BOE and H_2SO_4 to the silicon substrate for approximately 20 to 30 seconds.

21. (Original) The method for forming a contact plug of a semiconductor device according to claim 18:

wherein the step of H_2 baking further comprises treating the silicon substrate at a temperature of approximately 700 to 1,000°C for approximately 60 to 300 seconds.

22. (Original) The method for forming a contact plug of a semiconductor device according to claim 18:

wherein the epitaxial single crystal silicon portion comprises a substantially conical or pyramidal structure grown on the exposed portion of the silicon substrate; and

the second epitaxial silicon portion is grown on an exposed surface of the epitaxial single crystal silicon and on a sidewall of the contact hole.